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M. Bodnicki / M. Sęklewski / R. Grzelak

Practical realisation of the microrobot – an amphibian simulator

INTRODUCTION

There is popular tendency in microrobotics to design objects inspired by mechanical solutions of the Nature [3]. The directly inspiration for authors were works of *Ijspeert at team* [1,2], especially presented algorithms of the motion and analysis of the walk/swim phases using by amphibian animals. Object of the modeling was salamander - Type**:** *Chordata* - Phylum: *Amphibia* - Family: *Salamandridae.*

The presented works had following stages: design of electromechanical components, adaptation of control algorithms and implementation of them on PC and test of work of prototype.

There were following assumptions:

- Modular structure (with use of a number of similar elements) – ready for modifications, especially localization of the sensor system (like microcamera, contact sensors, etc.)
- Battery supply as a option (in first stage – application of supply unit and cable connector),
- PC computer as a main logic unit and platform for control software,
- Hobby DC servodrives as actuators with microcontroller as a first level of control,
- Symbolic (in first stage) readiness for swimming (only in algorithms of control and structure of the body, without waterproof body and active draught).

THE STRUCTURE OF THE MICROROBOT

In the modular structure of the robot the three parts of the body: head, thorax and tail are build from only two kinds of modules – cold in text as A and B module. The B module (leg module) is adapted A module. This solution was effective and profitable from point of view of costs of the project. The block diagram of all structure of microrobot is presented on Fig 1).

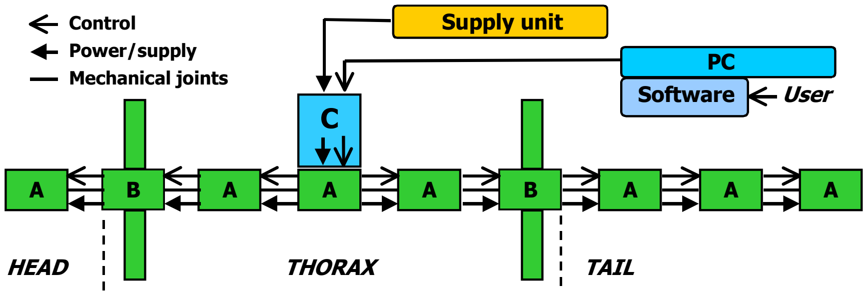

Fig. 1. The assumed scheme of the modular structure of the salamander-robot [4]
A – basic module of a body (head, thorax, tail), B – legs module; C – controller

There are following features of the modules:

- A–type – basic element of the body, with characteristic details: symmetric design, coupling element, one rotary servodrive (with pusher for realisation of angular movement between adjacent modules);
- B–type – the leg module built on A–type and equipped with additional two leg units; each leg unit is driven by next two servodrives with gears.
- Additionally the mechanical construction of a each module has special space for two AA type batteries (but prototype is supplied from outside source). The A-type modules are presented on Fig. 2.

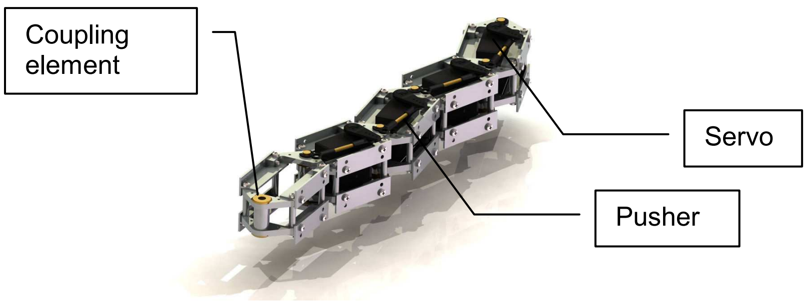

Fig. 2. The view of set of A-type modules used in thorax of the salamander-microrobot

The possibility and quality (realism) of the walk depends on the degrees of freedom in joints of the legs. The structure apply in the robot consist from two joints and two-segment legs (a tight and a shinbone, without a feet). The scheme of the leg is shown on Fig. 3.

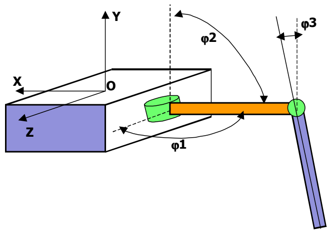

Fig. 3. A scheme of the leg [3] (description in the text)

A **φ1** angle (in shoulder joint) - this degree of freedom establishes length of the step of quadruped. From point of view of realization of a translation changes of this angle is the most important. The range of the φ1 angle is usually about π, but could measure to 2π. In robots is possible to generate the movement using only this degree of freedom – with legs sliding on a surface (but there is necessary blocking mechanism for support phase), e.g. by change of a friction coefficient according to move direction like "seal skin" for skiing.

A **φ2** angle (in the shoulder joint) - this degree of freedom is very important during the movement because establishes rise of the leg in carriage phase. The φ2 angle gives the change of leg position in carriage phase – which enables avoiding of obstacles as well as to distinguish legs in support phase. The range of the φ2 angle is usually about 1/4π, but value to 2/3π is better for bigger obstacles.

A **φ3** angle (in the elbow joint) - during the walk of the quadruped this angle makes possible change of the trajectory – movement by the line, curve or sideways (than the length depends on φ3 and φ1 is an equivalent of φ3). The end of the leg can be located in the selected point in the space (according to kinematic of the mechanism). The range of the φ2 angle is usually about 1/4π, and for folding of the legs this angle has to measure to π. It means that the realization both swim /walk phases and realistic turn depends on this angle.

The B-type module (basis for the legs) is presented on Fig. 4 and the practical realization of the leg anatomy in B-type module is presented on Fig. 5.

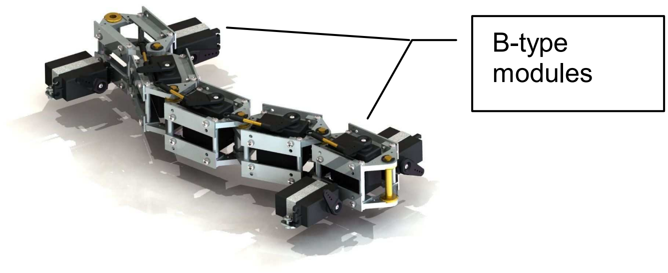

Fig. 4. The view of two B-type modules connected to the set of A-type thorax modules

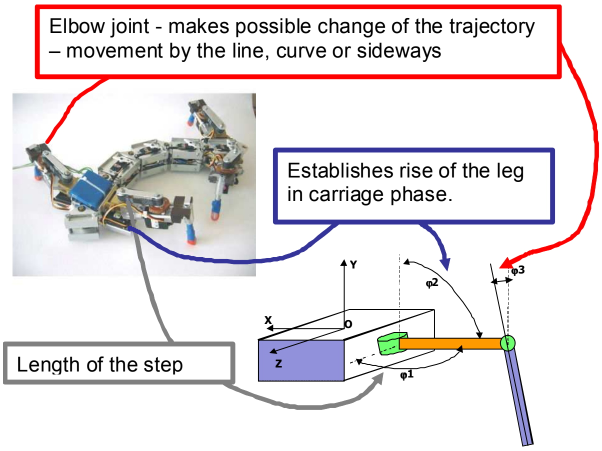

Fig. 5. Practical realization of the leg anatomy in B-type module

THE CONTROL OF THE MICROROBOT

The elementary procedures of the movement of the salamander are taken from the basic works of *A.J. Ijspeert* [1,2]. The fundamentally is description like wave of the neural activity of the animal generates wave of motions of the body - which is going from the head to tail according to formulas (1),(2) – during swimming and (3) – during walk [1,2].

$$A_i = a \cdot sin(\omega t - \lambda_i) \qquad (1)$$

$$\lambda_i = i \cdot 2\pi / n \qquad (2)$$

Where:

A_i – input of „i" segment of the body (interpreting as angle of bow of such segment),

a – amplitude,

ω – circular velocity,

t – time,

λ_i – phase angle for „i" segment, n – number of segments.

$$A_i = a \cdot sin(\omega t - \lambda_i) \tag{3}$$

Where for thorax: λ_I = 0 and for head as well as tail: $\lambda_i = \pi$. Additionally the movement of legs (changes of φ1, φ2 and φ3) is realized. Characteristic positions of the legs during walk are presented on the Fig. 6.

Fig. 6. Phases of the walk – 3D visualization of the microrobot

As the actuators systems in the microrobot the set of 18 servodrives (hobby-type) with SK18 controller is used. Transmission from PC "master unit" is realised via RS232 in typical transmission protocol. Servodrives are control by PWM signals with structure of the frame presented on Fig. 7.

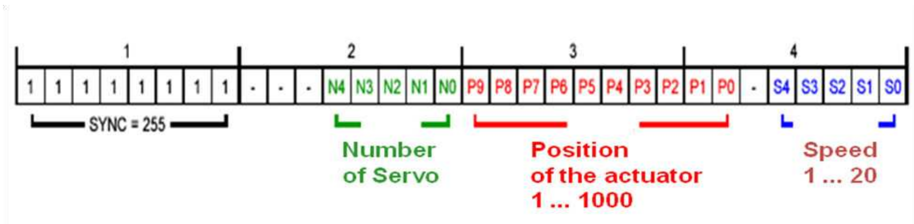

Fig 7. Transmission frame realized by the SK18 controller

The control software (master) is an integrated part of the robot. In presented phase of the works operator of PC microcomputer realizes all control options. The block diagrams of the main algorithms are presented on Fig. 7 [4]. In maintained paper [4] briefly description of the organization of the control panel of the operator is also placed. The decision for the operator (after choice of between walk/swim modes) could be only – straight on, left or right – but of course a number of parameters of the move is adjustable (like a speed, circle of the turn). The behavior of the body elements is suitable automatically.

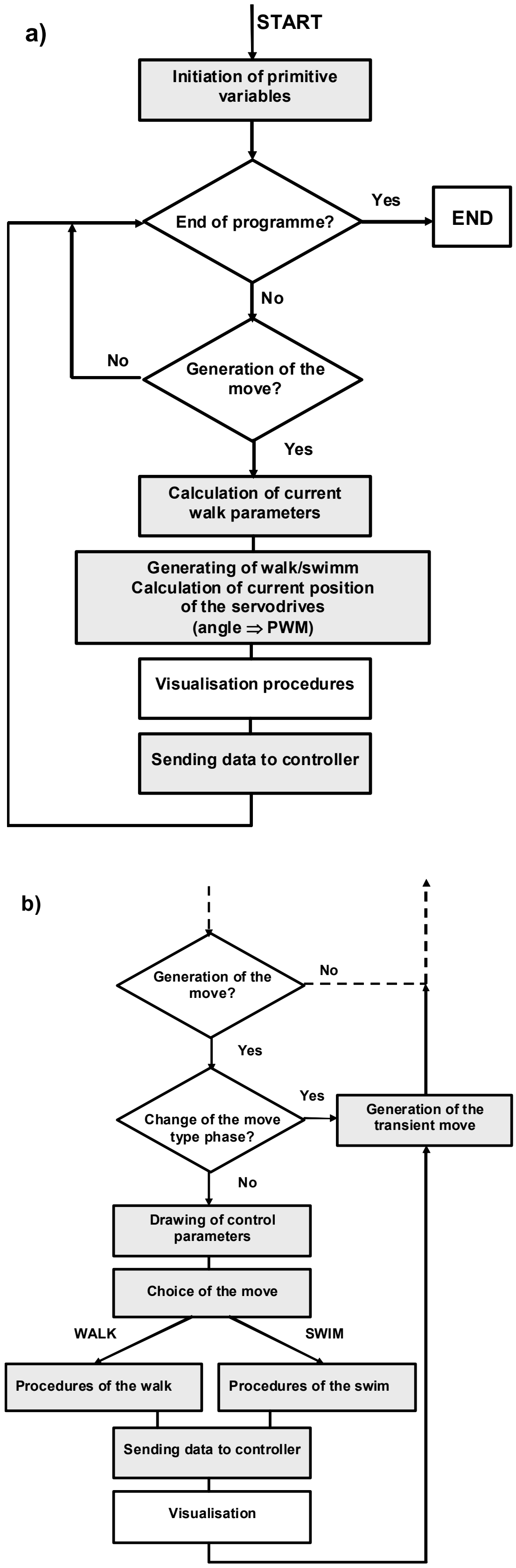

Fig. 4. Control algorithms of the main procedures realized in microrobot [4]

a – main; b – changes from walk to swim / swim to walk position

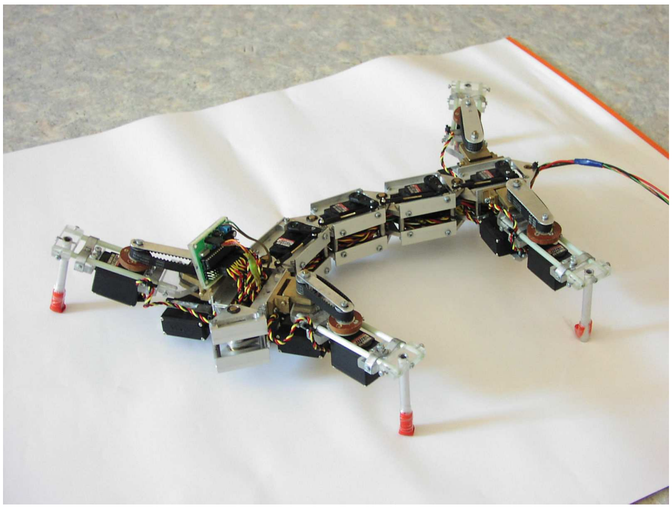

Fig. 8. General view on amphibian-microrobot

CONCLUSION

The prototype of salamander like microrobot was design and build, as well as the control software was compiled (the general algorithms by [1,2] have been applied) . Tests confirm correctness of algorithms and their implementation. After first prototype the next version was built (presented on photos in the paper) characterized by stronger servos and changes in transmission of power elements.

Actually phase of the work assumes study of the sensors systems. There are contact sensors in the legs, noise (sound) sensors and – first of all – the vision system with microcamera. The two kinds of observation/recognition of the environment are taken under consideration: simply mode (information for operator – for inspection mode of use and the second one – automatically recognition of the area in view of camera and generation of the control signals suitable for autonomic walk of robot.

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